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Exercise Recommendations After Total Joint Replacement

A Review of the Current Literature and Proposal of Scientifically Based Guidelines

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Abstract

This article presents a literature review of the current recommendations regarding sports after total joint replacement and also suggests scientifically based guidelines. Patients should be encouraged to remain physically active for general health and also for the quality of their bone. There is evidence that increased bone quality will improve prosthesis fixation and decrease the incidence of early loosening. To recommend a certain activity after total knee or hip replacement, factors such as wear, joint load, intensity and the type of prosthesis must be taken into account for each patient and sport. It has been shown that the reduction of wear is one of the main factors in improving long-term results after total joint replacement. Wear is dependent on the load, the number of steps and the material properties of total joint replacements. The most important question is, whether a specific activity is performed for exercise to obtain and maintain physical fitness or whether an activity is recreational only. To maintain physical fitness an endurance activity will be performed several times per week with high intensity. Since

load will influence the amount of wear exponentially, only activities with low joint loads such as swimming, cycling or possibly power walking should be recommended. If an activity is carried out on a low intensity and therefore recreational base, activities with higher joint loads such as skiing or hiking can also be performed. It is unwise to start technically demanding activities after total joint replacement, as the joint loads and the risk for injuries are generally higher for these activities in unskilled individuals. Finally, it is important to distinguish between suitable activities following total knee and total hip replacement. To recommend suitable physical activities after total knee replacement, it is important to consider both the load and the knee flexion angle of the peak load, while for total hip replacement, which involves a ball and socket joint, the flexion angle does not play an important role. During activities such as hiking or jogging, high joint loads occur between 40 and 60° of knee flexion where many knee designs are not conforming and high polyethylene inlay stress will occur. Regular jogging or hiking produces high inlay stress with the danger of delamination and polyethylene destruction for most current total knee prostheses. Based on these design differences between hip and knee replacements it is prudent to be more conservative after total knee arthroplasty than after total hip arthroplasty for activities that exhibit high joint loads in knee flexion.

Worldwide more than 500 000 total joints are implanted yearly.[1] Hence, besides general details associated with age such as dementia, chronic lung disease, osteoarthritis, reduced eyesight and impaired proprioception,[2] the possibility of a patient having a total joint replacement must also be considered when an individual exercise regimen is recommended. The aim of this article is to provide a literature review concerning the current recommendations regarding sports after total joint replacement and to suggest new guidelines that are based on current scientific and biomechanical knowledge.

1. Long-Term Results from Total Joint Replacements in Young and Active Patients

Some retrospective studies in patients performing sport activities after total joint replacement have reported contradictory results.[3-10] For example, recreational exercise had no significant deteriorating effect on total hip arthroplasties (THA) for up to 5.8[3] or 9 years.[10] Kilgus et al.,[5] on the contrary, found that active patients were at a significantly increased risk for revision surgery as a result of aseptic loosening. The harmful effects of sports participation were not noticed until 10 years postoperatively. Several other studies have confirmed that total hip replacements have a higher incidence of early loosening and failure in younger and consequently more active patients.[11-15] In the Swedish National Hip Arthroplasty Register, men younger than 55 years of age showed a revision rate of almost 20%, while the rate was only about 5% for older patients after 10 years.[16] This increased revision rate in younger patients may be attributed to an increased activity of this population group.

Results are also contradictory with regard to total knee replacement. In patients younger than 55 years of age, a survival rate for their knee prostheses of 96% at 10 years was reported.[17,18] It was concluded that total knee arthroplasties (TKA) appear to maintain their excellent results over time without the deterioration seen in THA in younger patients. Diduch et al.[19] followed 108 TKA in 84 patients with osteoarthritis who were younger than 55 years. Some of the patients even showed regular participation in activities such as tennis, skiing, bicycling or strenuous farm construction. The mean follow-up time was 8 years, and ranged from 3 to

18 years. Ninety-four percent had a good or excellent function.

Mintz et al.,[20] on the other hand, performed an arthroscopic evaluation of the tibial plateau in 33 patients an average of 4.5 years after total knee replacement. Patients whose prostheses were unsuccessful during the follow-up period were younger, larger and more active than patients whose implants were successful. The Swedish Knee Arthroplasty Register showed a 10-year revision rate of only 6% in patients older than 74 years while it was increased by a factor of three (18%) in patients younger than 65 years.[21]

2. Physical Activity After Total Joint Replacement

Patients who have symptomatic osteoarthritis of the knee joint typically have less strength, endurance for exercise and aerobic capacity than patients who do not have osteoarthritis.[22] Many of these effects can be attributed to a decline in functional activities because of osteoarthritic pain. Joint replacement operations have been shown to relieve pain, improve function, increase mobility and psychological well being. Furthermore, total joint replacements are a predictable and successful treatment for the painful osteoarthrosis with a high patient satisfaction[23] and good long-term results.[17-19,21] A modern total joint replacement has a >90% chance of surviving 10 to 15 years.[19,21,24] The improvement of pain and function after total joint replacements also allows patients to increase their physical activity and some patients even participate in sporting activities.[3,10,19,22] A marked increase in participation in four common types of recreational exercise, such as, walking, cycling, cross-country skiing and swimming, after total hip replacement was shown.[10] Preoperatively, only 2% of patients performed regular walking, and this increased to 55% postoperatively. Cycling increased from 7% preoperatively to 29% postoperatively, swimming from 13% preoperatively to 30% postoperatively, and cross-country skiing increased from 0% preoperatively to 9% postoperatively.

An increase in the Tegner activity score from an average of 1.3 points preoperatively to 3.5 points postoperatively was also found in TKA.[19]

Ries et al.[22,25] evaluated cardiovascular fitness before and after hip and knee arthroplasty and found a significant improvement in exercise duration, maximum workload, and peak oxygen consumption after two years. These findings demonstrate that patients are limited by the osteoarthritis and an improvement of joint function after total joint replacements allows them to increase their activities and improve physical fitness.

However, only patients who had a high activity level preoperatively returned to sports after total joint replacement while inactive patients seemed to remain less active despite the improved joint function.[26] Bradbury et al.[26] evaluated 160 patients who had undergone total knee replacement with regard to return to sports activity. Eighty-one patients did not regularly participate in any sports before surgery and none of these patients took up sports after surgery. Seventy-nine patients participated in sports before surgery and 51 of these patients returned to regular exercise postoperatively. These patients were more likely to return to low-impact activities such as bowls than high-impact activities such as tennis. Seventy-seven percent of patients who participated in regular exercise in the year before surgery returned to sports while only 35% of patients who had been inactive in the year before surgery returned to sports. The preoperative activity level was also the most important factor regarding sport activities postoperatively in THA.[3] The most common sports before and after total hip replacement in this study were hiking (41%) and swimming (35%). Seventeen percent of patients even resumed jogging and 10% cycled on a regular basis, postoperatively. Most patients performed these activities preoperatively. It seems that active patients with osteoarthritis would like to resume an active lifestyle after total joint replacement and enjoy participation in sport activities, and these patients need careful advice on the most suitable activity. On the other hand, patients who are inactive preoperatively tend to remain inactive after total joint replacement, and such patients should be encouraged to start some exercise to improve overall fitness. However, the question remains: which activities?

3. Exercise Recommendations After Total Joint Replacement

Many studies provide recommendations about sport participation after total joint replacement.[1,3,4,6,7,27-34] Dorr[32] recommended activities such as swimming, hiking, bicycling, walking and golfing for patients after total joint replacement or osteoarthritis. Dubs et al.[3] even included sport activities such as jogging, hiking, mountaineering and tennis in their recommendations, based on a retrospective study. Only activities such as riding, contact sports and acrobatics, were discouraged by these authors. McGrory et al.[33] sent a questionnaire that identified 28 common sports to 15 consultant surgeons, to two fellows in adult orthopaedic reconstruction and to thirteen fifth-year orthopaedic residents. The response options for each activity was 'yes', 'no' or 'depends'. Sports in which 75% of surgeons would not allow participation were labelled 'not recommended' whereas sports in which 75% of surgeons would allow participation were labelled 'recommended'. Sport activities which <75% of the surgeons did recommend, were labelled 'intermediate'. The recommendations for THA and TKA were similar in this study. Running, water-skiing, football, baseball, basketball, hockey, handball, karate, soccer and racquetball were not recommended after THA or TKA. Cycling, sailing, bowling, scuba diving and golfing were recommended after THA and TKA whereas speed walking, hiking, ice skating, backpacking, doubles tennis, ballet, aerobics, alpine skiing, softball, volleyball and single tennis were labelled intermediate.

Another study[34] categorised sports in low-, moderate- or high-demand activities. No reasoning was mentioned as to why a certain activity was labelled as moderate- or high-demand. For example, jogging was assumed a moderate, and hiking a high-demand activity. Cycling was labelled moderately demanding while walking was low demand. In the study of McGrory et al.,[33] on the other hand, cycling was recommended, jogging was not recommended, and hiking and speed walking were intermediate. In a review article[1] concerning athletic activities after total joint replacements, 54 members of the Hip Society and the Knee Society were surveyed regarding their recommendations for athletics and sports participation for their patients. The 54 responses were analysed statistically and a consensus recommendation for each activity was obtained and published[1] (tables I and II).

Since prospective randomised studies on athletic activities after joint replacement are not available in the current literature, recommendations are based upon the opinion of orthopaedic surgeons. Biomechanical analyses of knee and hip joint loads during these sport activities were rarely considered. Obviously, most surgeons conservatively recommend low-impact activities such as swimming, cycling and walking, and discourage high-impact activities such as football, handball, basketball, soccer or hockey. No consensus in the current literature exists for many activities such as power walking, cycling, hiking or jogging. Also, most of the present articles do not distinguish between total knee and total hip replacement regarding their recommendations.[32-34]

4. Proposal of Scientifically Based Guidelines

Most individuals might have a good feeling about the effects of different sport activities on a knee or hip joint as they know from their own experiences, such as muscle soreness or overuse injuries, how strenuous a certain sport activity is. However, physicians and coaches should be able to instruct their patients about the risks and recommend sport activities after total hip or total knee replacement according to scientific knowledge rather than 'gut feelings'. In the following section, established factors that influence wear and long-term results from total joint replacements will be

Table I. Consensus recommendations for activity after total hip arthroplasty (1999 Hip Society Survey)[1]

Recommended/allowed
Stationary bicycling
Croquet
Ballroom dancing
Golf
Horseshoes
Shooting
Shuffleboard
Swimming
Doubles tennis
Walking
Allowed with experience
Low-impact aerobics
Road bicycling
Bowling
Canoeing
Hiking
Horseback riding
Cross-country skiing
Not recommended
High-impact aerobics
Baseball/softball
Basketball
Football
Gymnastics
Handball
Hockey
Jogging
Lacrosse
Racquetball
Squash
Rock climbing
Soccer
Singles tennis
Volleyball
No conclusion
Jazz dancing
Square dancing
Fencing
Ice skating
Roller/inline skating
Rowing
Speed walking
Downhill skiing
Stationary skiing
Weight-lifting
Weight machines

outlined. Taking these data into consideration will provide more scientifically based guidelines.

Issues that must be taken into account for each patient and sporting activity include:

- wear of total joint replacements
- joint load and moments during sport activities
- activity and fixation of prosthesis
- recreation or exercise
- experience
- difference between THA and TKA.

4.1 Wear of Total Joint Replacements

Bone destruction as a tissue response to particles is now a well recognised problem in total joint replacements.[35] Up to 500 000 submicron-sized polyethylene particles are released with each step.[36] These small polyethylene particles can activate macrophages, which produce factors such as stromelysin, prostaglandin E2, interleukin-1, and tumour necrosis factor. These factors are thought to explain the progressive osteolysis and aseptic loosening seen in total joint implants.[37] It is evident that the major long-term problem in total joint replacement is polyethylene wear.[38] Factors that can reduce wear and improve long-term results can be separated into surgically-controlled factors, patient-based factors, material properties of the components, and design-related factors. Even though a technically perfect reconstruction of an arthritic joint plays an important role for the functional and long-term result it is not the purpose of the present review to give recommendations about the surgical technique, nor about different designs or the development of new materials. We shall concentrate on patient-based factors, which can be influenced by the surgeon's and physician's dietary and activity suggestions.

The total volume of wear particles produced strongly depends on the sliding distance or the amount of steps (linear relationship), on the applied load (exponential relationship) and the surface roughness (exponential relationship).[39] An enormous variability of activity levels amongst patients of all age groups exists.[40,41] The amount of steps of 243 patients ranging in age from 17 to 83 years was investigated using a pedometer.[40] The number of steps/day ranged from 1600 to 35 500 for male patients and from 1200 to 32 600 for female patients. If this range of steps was extrapolated to steps/year the activity level may range from about 500 000 steps to almost 13 million steps/year. Age only correlated weakly with the number of steps (r = –0.42) or the distance walked (r = –0.44) which meant that only 16% of the variability was explained by the factor age. A similar study was performed after total knee or total hip replacement.[41] Patients after THA (947 905 steps/year) were significantly more active than patients after TKA (641 305 steps/year). Similar to Seedhom and Wallbridge's[40] study there was a great variability in walking activity and only a weak correlation existed between age and activity level. The activity level seems the most variable patient-related factor and the enormous activity differences amongst patients may well explain why some prostheses last for many years and others loosen earlier. The low correlation between walking activity and age may also explain why some studies[17-19] found similar results for TKA in younger and older patients. It seems that the activity level may be a much better parameter than age for the assessment of total joint arthroplasties. Indeed, one study[42] showed that wear is a function of use. They found a volumetric wear of about 34mm^3 per million cycles. The average patient bodyweight was 79kg and an adjustment was made for a 70kg patient, which yielded an average volumetric wear of 30mm^3 per million cycles for a 70kg patient. Since the most common activity in this study was walking, the good correlation between the amount of steps and the wear volume is well explained.

Besides the number of steps per day or year (sliding distance), the joint load (which is given by the type of activity), must also be taken into account for the activity level of a patient. If patients resume activities with high joint loads, the amount of wear could increase exponentially. Another study[4] followed two cohorts of 50 matched patients after total hip replacement over 5 to 10 years. One group consisted of an active group in which all members participated in downhill or cross-

Table II. Consensus recommendations for activity after total knee arthroplasty (1999 Knee Society Survey)[1]

Recommended/allowed
Low-impact aerobics
Stationary bicycling
Bowling
Golf
Dancing
Horseback riding
Croquet
Walking
Swimming
Shooting
Shuffleboard
Horseshoes
Allowed with experience
Road bicycling
Canoeing
Hiking
Rowing
Cross-country skiing
Stationary skiing
Speed walking
Tennis
Weight machines
Ice skating
Not recommended
Racquetball
Squash
Rock climbing
Soccer
Singles tennis
Volleyball
Football
Gymnastics
Lacrosse
Hockey
Basketball
Jogging
Handball
No conclusion
Fencing
Roller blade/inline skating
Downhill skiing
Weight-lifting

country skiing and also regularly in trekking, while the other group was more sedentary, participating only occasionally in swimming or trekking, and not participating in skiing. The active group showed a linear wear of 2.42mm after an average follow-up of 6 years, whereas the linear wear was only 1.16mm after 7 years in the less active group. The active patients who participated in trekking and skiing showed an annual linear wear rate of 0.4 mm, which was a factor of 2.5 higher than the wear rate of the inactive patients, which was 0.16mm.[4] Schmalzried et al.[42] found an average linear wear rate of 0.14 mm/year, which was similar to the inactive group in the study of Gschwend et al.[4] It can be concluded that wear, at least in total hip replacements, strongly depends on the number of steps and also on the joint load, which is given by the the patient's bodyweight and the type of activity. No studies exist yet for total knee replacements, but there is evidence that these laws also apply for total knee replacements.[28,43,44] It was shown, for example, that patients who showed increased flexion moments also demonstrated an increased risk of tibial component loosening.[44]

Table III. Hip joint loads during different activities

Activity	Hip joint load (× bw)	References
Standing on two legs	0.8	45,46
Standing on one leg	3.2	
Straight leg raise	1.9	
Walking at 1 km/h	2.9	
Walking at 5 km/h	4.7	
Jogging at 5 km/h	5.0	
Jogging at 7 km/h	5.4	
Stumbling	8.7	
Cycling low resistance (40W)	0.5	
Cycling high resistance	1.4	
Jogging at 12 km/h	6	48
Alpine skiing long turns, flat slope	4.5	
Alpine skiing long turns, steep slope	6	
Alpine skiing short turns, flat slope	5.5-6	
Alpine skiing short turns, steep slope	7-8	
Alpine skiing small moguls	8-9	
Alpine skiing large moguls	10-15	
Cross-country skiing classical	4-5	
Cross-country skiing skating	4.5	
Walking at natural speed	3.2-6.2	49
Stair ascent	3.4-6	
Car entry	5-8	
Car exit	4.5-8	
Bath entry	4.6-6.6	
Stair ascent	5	47
Stair descent	5.6	
Ramp ascent	6.8	
Ramp descent	6.5	

bw = bodyweight.

4.2 Joint Loads and Moments During Different Activities

Since wear and joint load have an exponential correlation,[39] a good knowledge about joint loads that occur during different activities is important to recommend a specific exercise. Tables III and IV summarise published data about hip and knee joint loads during some daily and athletic activities. A number of these data were obtained by *in vivo* measurements of a telemeterised total hip replacement,[45-47] while others were estimates from joint models.[47-62]

A few additional considerations about some exercises are noteworthy.

4.2.1 Speed Walking

An important issue is whether fast walking is an intense enough activity to elicit a cardiovascular-training effect and how fast a patient must walk to gain some training effects. In a study[63] of >300 healthy adults, 67% of men and 91% of women achieved a training heart rate (e.g. >70% of maximal heart rate) when asked to walk a mile briskly. In men over the age of 50 years, 83% achieved a training heart rate.[63] Even well trained young men were able to elevate the heart rate into the target training range. Duncan et al.[64] randomised 102 sedentary women ranging from 20 to 40 years of age to four treatment groups. Fifty-nine completed the study (16 aerobic walkers with 8 km/h; 12 power walkers with 6.4 km/h, 18 strollers with 4.8 km/h and 13 sedentary controls). The participants all walked 4.8 km/day, 5 days/week at the assigned speed for 24 weeks. When the maximal oxygen

Table IV. Knee joint forces during different activities

Activity	Knee joint load (× bw)	Reference
Walking at 5.4 km/h	3.4-4	43
Walking	3.0	50
Walking at 5 km/h	2.8	51
Walking at 7 km/h	4.3	
Walking	3.5	52
Cycling at 120W	1.2	53
Stair ascent	4.3	54
Stair ascent	5.0	55
Stair descent	3.8	54
Stair descent	6	56
Ramp ascent	4.5	54
Ramp descent	4.5	
Ramp descent at 5.4 km/h	7-8.5	43
Squat descent	5.6	57
Isokinetic knee extension	up to 9	58
Jogging at 9 km/h	8-9	59
Jogging at 12.6 km/h	10.3	60
Running at 16 km/h	up to 14	
Bowling on asphalt alleys	up to 12	61
Skiing medium steep slope		62
beginner	10	
skilled skier	3.5	

bw = bodyweight.

consumption was reassessed after 24 weeks, the sedentary control group showed a decrease of 6%, the strollers improved by 4%, the power walkers by 9% and the aerobic walkers by 16%. Hence, there was a significant and dose-dependent training effect. The investigators concluded that moderate to fast walking (e.g. 6 to 8 km/h) provided a safe and effective activity for young- to middle-aged women to achieve significant gains in cardiorespiratory fitness levels. Hence, to evaluate the knee and hip joint loads during power walking, speeds of 6 to 8 km/h must be considered. It is known that the joint moments and joint loads increase with increasing speed. Paul[51] estimated knee joint loads at slow, normal and fast walking speeds. Normal and fast walking speeds corresponded to average speeds of 5.3 and 7.2 km/h, respectively. The knee joint loads were 2.8 × bodyweight (bw) and 4.3 × bw, respectively. Hence, during power walking tibio-femoral compressive loads of 4 to 4.5 × bw must be assumed. Hip joint loads are within this range during power-walking.[46]

4.2.2 Cycling

Ericson and colleagues[53,65,66] performed several studies on the biomechanics of ergometer cycling and found that the mean tibio-femoral compressive force was 1.2 × bw when the participant was cycling 60 rpm, and with a workload of 120W. The tibio-femoral joint force increased with increasing workloads and was not influenced by changes of pedalling rates. However, the tibio-femoral compressive force could be decreased with increased saddle height. The hip joint load during cycling also remained below 1.5 × bw.[45]

4.2.3 Jogging

Bergman et al.[46] investigated the *in vivo* forces of a telemeterised total hip replacement in an 82-year-old patient. Despite being very active he was only able to jog at a speed of 6 to 8 km/h, which can also be achieved by fast walking. The hip joint load at this speed was still >5 × bw.

As with walking, the hip and knee joint moment and load during jogging is dependent on the speed. Winter[59] investigated the kinematics and kinetics of the hip, knee and ankle joint during slow jogging (9.7 km/h). He found a knee joint moment of 2.7 Nm/kg bw. When patients were running with a speed of 16 km/h the knee joint moment increased to 4 Nm/kg.[67] Hence, the moment doubles if the speed is doubled. The estimated load during slow jogging in the knee joint was about 7.5 to 8 × bw for male patients and 8.5 to 9 × bw for female patients. During fast running the knee joint moment is much higher and loads of 10 × bw and more are realistic.[60]

4.2.4 Hiking

In a Swiss study,[3] 41% of active patients after total hip replacement resumed hiking. Subjectively, it is known that downhill walking places large loads on the knee joint as evidenced by many hikers experiencing quadriceps muscle soreness after downhill walking. Indeed, fast downhill walking has been shown to produce knee joint loads up to

8 × bw.[43] Using ski poles for downhill walking has been shown to reduce the knee joint loads by as much as 20%.[68]

4.2.5 Summary

To the best of the author's knowledge no hip or knee joint load could be found for activities such as rowing, swimming or Aqua-Fit. To further improve scientifically based guidelines for exercise recommendations after total hip or knee joints studies involving joint loads during more activities would be helpful.

As a general guide, the following hip and knee joint loads can be assumed. During daily activities, loads of 3 to 4 × bw occur, while during sport activities loads of 5 to 10 × bw might occur. Loads of up to 25 × bw have been reported during extreme activities such as weight-lifting.[69] Furthermore, the moments and joint loads of the hip and knee during most endurance activities such as walking, hiking and jogging, strongly depend on the speed. The faster we walk or run the larger the joint loads. For activities such as skiing, joint loads can vary significantly depending on the style.[62] Short turns increase joint loads compared with longer turns. Furthermore, moguls will increase the loads.

4.3 Inactivity and Fixation of the Prosthesis

There is strong evidence that a total joint replacement in an inactive patient will show less wear than that of an active patient. However, it does not seem prudent to condemn a patient to inactivity after a total joint replacement. Functional changes that are associated with inactivity include reduced aerobic fitness, loss of co-ordination and postural reflexes, loss of muscle mass and calcium extraction or osteoporosis, while physical fitness and exercise reduce all cause mortality, anxiety and depression, improve muscle co-ordination, muscle strength and bone density.[2] Physical activity can even have beneficial effects for total joint replacement. Firstly, improved muscle strength and co-ordination will prevent patients from falls and injuries. Secondly, exercise will increase bone density and improve prosthesis fixation. Wear is one factor while fixation of the prosthesis is another. Indeed, in the study of Dubs et al.,[3] the revision rate was smaller amongst active patients (1.6%) than amongst inactive patients (14.3%). The authors concluded that participation in sport after total hip replacement would produce a regeneration of bone and improve the osseous bed for the prosthesis. This finding could also be confirmed by another study[9] that found a lower rate of loosening of THA in active patients. In both studies the mean follow-up time was below 10 years. Gschwend et al.[4] followed a cohort of 50 active patients and a matched control of less active patients for 5 and 10 years. At the 5-year follow-up, 5 out of 60 prostheses had signs of loosening in the inactive group while none of the active group had signs of loosening. After 10 years, 30 patients remained in the active group and 27 in the inactive group. At this 10-year follow-up, two patients of the active group had signs of loosening while no new incidences of loosening were found in the inactive group. Furthermore, in the study of Kilgus et al.,[5] the effects of increased loosening in active patients due to wear particles occurred after 10 years. Hence, there is evidence that a balance exists between too little activity, leading to decreased bone density and early loosening (before 10 years), and too much activity, leading to increased wear and late loosening (after 10 years). Consequently, patients after total joint replacements should exercise regularly and not be condemned to inactivity as physical fitness and muscle strength have beneficial effects for general health, muscle co-ordination, bone density and also for prosthesis fixation.

4.4 Recreation versus Exercise

A most important issue to consider is whether a specific activity is performed with high intensity for exercise (to obtain and maintain physical fitness), or whether an activity is for recreation. To emphasise this point, let us assume that patient A cycles, patient B speed walks and patient C jogs, after a total hip replacement to develop and maintain cardiorespiratory fitness. All three patients follow the guidelines of the American College of Sports

Medicine and exercise three times a week for 40 minutes. Patient A cycles with 80 rounds/min, patient B walks with 150 steps/min or 75 cycles/min and patient C jogs at a speed of 10 km/h with 180 steps/min or 90 cycles/min. This adds up to 499 200 cycles/year for patient A, 468 000 cycles/year for patient B and 561 000 cycles/year for patient C. Hence, each patient will perform about half a million additional cycles during exercise. A wear volume of 30mm^3 per 1 million walking cycles was found for a 70kg person.[42] Since wear shows a strong correlation to load, this must now be considered. Cycling produces the lowest load for the knee and hip joint, being about 1.2 × bw. Normal walking is about 3.5 × bw and power walking about 4 to 5 × bw. Jogging produces the highest loads of up to 7 or 8 × bw for the hip and knee joint. Even though the correlation between load and wear is exponential,[39] a simple linear relationship is assumed. Power walking has a 42.5% and jogging a 130% load increase compared with normal walking, while cycling has a load reduction of 300%. Hence, the activity-induced annual wear rate will be about 5mm^3 for patient A, about 21mm^3 for patient B and 35mm^3 for patient C.

As can be seen, an appropriate activity can influence the wear rate by a factor of up to 7 and hopefully also significantly influence the longevity of a total joint replacement. Patients are advised to perform activities like cycling, swimming, Aqua-Fit and possibly power walking as an exercise regimen for cardiorespiratory fitness. Activities such as jogging, hiking, tennis or other sports with high joint loads should not be performed as a regular endurance activity. It is a different matter however, if patients would like to resume these activities for recreation. Skiing for 1 or 2 weeks a year, playing tennis for pleasure (avoiding competition, fast sprints or jumps) or hiking on weekends will not add a great amount of steps and may well be accepted. There are ways to reduce joint loads during several activities. During mountain hiking, patients should be advised to avoid steep descents, short-cuts and walk slowly downhill.[28] They should use ski poles, as this can reduce the load on the joints by as much as 20%.[68] During skiing steep slopes, hard snow conditions or moguls should be avoided.

The same applies for TKA. Low-impact activities such as cycling, Aqua-Fit or swimming are ideal activities to obtain cardiorespiratory fitness.[28] Hiking or sports that involve running or high joint loads should be avoided as regular exercise, as was shown in a biomechanical study on endurance sports recommendations after TKA.[28]

4.5 Experience and Risk of Injuries

Another essential factor is the amount of experience a patient has gained in a certain sporting activity. This is especially important for activities such as mountain hiking, cross-country and downhill skiing, horse riding, mountain biking and tennis. It seems unwise for a patient to start these technically demanding sporting activities after a total joint replacement for several reasons.

The risk of injuries might be increased for these activities in inexperienced patients. There is preliminary evidence from Switzerland that individuals not regularly active, out of practice or inexperienced are at higher risk for sport accidents.[70] Even mountain hiking has a high rate of accidents or overuse injuries. An epidemiological study in Switzerland, for example, found that ice hockey, handball and soccer had the highest incidence of injuries in males, and this was followed by hiking.[71]

Furthermore, joint loads might be significantly increased for beginners compared with experienced individuals. For example, knee joint loads during skiing were estimated for skilled and untrained skiers.[62] It was found that the knee joint forces in the steering phase were not very high for highly skilled skiers (2775N). However, unskilled skiers tended to lean backwards and their knee joint forces increased heavily to 7463N. They further concluded that in icy snow conditions and in moguls the knee forces in low-level skiers might reach very high values.

4.6 Differences Between Total Hip Arthroplasties and Total Knee Arthroplasties

Mallon and Callaghan[6,7] investigated the effects of golf on THA and TKA. Participants, who had a single primary THA (n = 115) or TKA (n = 83) and no other joint arthroplasty, a minimum follow-up period of 3 years and who were playing golf a minimum of three times per week on average were recruited from 48 regional sections of the professional golfer's association of America. This cohort of patients was sent a questionnaire and recent postoperative radiographs were solicited from the patients' surgeons. Based on their study they concluded that many golfers improved their handicap after THA while it decreased after TKA. In addition, most golfers with a THA did not have pain while playing. After TKA the results were not as encouraging as after THA. Radiographic lucent lines occurred in 79% of cemented TKA, in 45% of uncemented TKA and in 54% of all TKA studied. Both the occurrence of radiographic lucent lines and the incidence of pain during and after play were higher for patients with TKA than with THA.

Hence, it is important to distinguish between suitable activities following total hip or total knee replacement. Total hip replacements are designed as a ball and socket joint. In TKA designs, on the other hand, the radius of the femoral component usually does not match the radius of the tibial component throughout the flexion range. In many total knee designs the femoral and tibial radiuses are conforming near extension and nonconforming in flexion. This specific contact geometry results in high contact stress above the yield point in flexion which can result in delamination and destruction of the inlay.[72] To recommend suitable physical activities after total knee replacement, it is important to consider both the load and the knee flexion angle of the peak load while for total hip replacement, which is a ball and socket joint, the flexion angle does not play an important role. Many total knee designs will show much smaller stress levels near extension than in flexion for the same load.[72] During activities such as hiking or jogging high joint loads occur between 40 and 60° of knee flexion where many knee designs are not conforming.[43] This will lead to very high polyethylene inlay stress. Hence, regular jogging or hiking with intense downhill walking produces a large overloaded area with the danger of delamination and polyethylene destruction for most current total knee prostheses. The author is aware of a patient who participated in a marathon run after total knee replacement despite being discouraged by the surgeon. The polyethylene inlay broke at the 35km mark due to severe delamination and destruction.[28] On the other hand, many patients resume jogging after total hip replacement without this deleterious effect. Based on these design differences between hip and knee replacements it is prudent to be more conservative after TKA than after THA for activities that exhibit high joint loads in knee flexion (jogging, mountain hiking).

5. Conclusion

Patients should be motivated to remain physically active after total joint replacement for general health, prevention of cardiac problems and also for improvement of bone quality and prosthesis fixation. However, the activity recommendations should be assessed for each patient. Active patients who would like to maintain or even improve cardiorespiratory fitness will have to exercise three to four times weekly for 30 to 40 minutes. These aerobic activities should be of low-impact, such as swimming, cycling, Aqua-Fit or power walking.

For patients who would like to continue sport on an occasional and therefore recreational basis, activities with higher joint loads, such as skiing, tennis and hiking can be recommended. Patients should also be alerted to joint-load–reducing measures such as the use of ski-poles during hiking, the use of cable cars for the descent, skiing on flatter slopes and avoiding icy conditions, the use of diagonal instead of skating techniques during cross-country skiing, cycling with low loads and higher frequencies and increasing saddle height. It is also unwise to start technically demanding activities such as skiing, mountain hiking, mountain biking, horse riding and tennis after total joint replacement as the joint loads and the risk for injuries are generally higher for these activities in unskilled individuals. Based on design differences between hip and knee replacements it is also prudent to be more conservative after TKA than after THA for activities that exhibit high joint loads in knee flexion such as jogging, or mountain hiking.

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